(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 April 2001 (19.04.2001)

PCT

(10) International Publication Number
WO 01/27910 A1

(51) International Patent Classification[7]: G09G 3/32

(21) International Application Number: PCT/EP00/09765

(22) International Filing Date: 5 October 2000 (05.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
99203341.5 12 October 1999 (12.10.1999) EP
00202915.5 21 August 2000 (21.08.2000) EP

(71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors: SILVESTRE, Guenole, C., M.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). SEMPEL, Adrianus; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). JOHNSON, Mark, T.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN BERKEL, Cornelis, H.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). PLANGGER, Guido; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

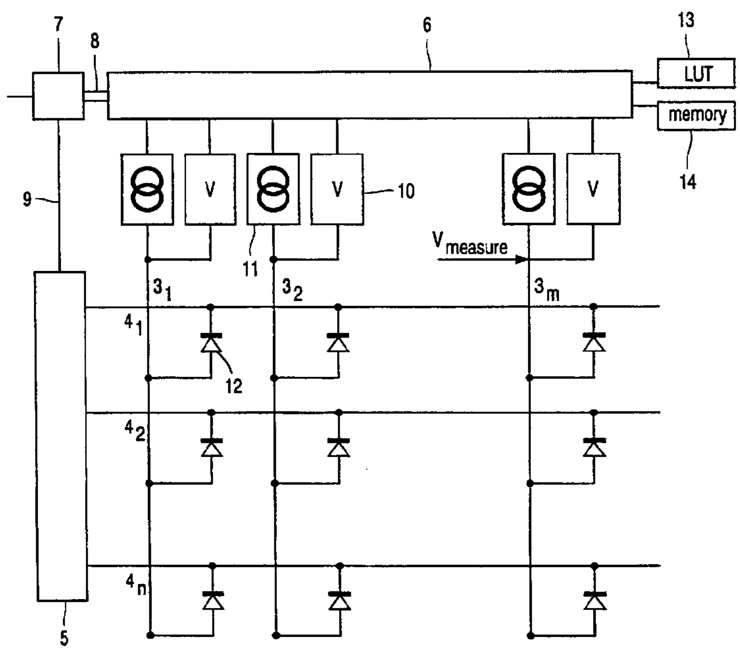
(74) Agent: BAELE, Ingrid, A., F., M.; Internationaal Octrooibureau B.V., Prof Holstlaan 6, NL-5656 AA Eindhoven (NL).

(81) Designated States *(national)*: JP, KR.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

(54) Title: LED DISPLAY DEVICE



(57) Abstract: The invention relates to a display device comprising one or more display elements, at least one of which comprises a light-emitting diode, and a driving unit for driving the one or more display elements. The driving unit comprises means for measuring the voltage across the light-emitting diode and means for adjusting the drive signal for the light-emitting diode, dependent on the measured voltage.

WO 01/27910 A1

LED DISPLAY DEVICE

The invention relates to a display device comprising one or more display elements, at least one of which comprises a light-emitting diode, and a driving unit for driving the one or more display elements.

Such display devices are known, e.g. from International Patent Application PCT/US98/08367 (Publ. No. WO 98/48403). This document describes matrix displays which comprise a plurality of picture or display elements that are arranged in rows and columns. The display incorporates a column data generator and a row select generator. In operation, each row is sequentially activated via a row line, where the corresponding pixels are activated, using the corresponding column lines. In a passive matrix display, each row of pixels is illuminated sequentially one by one, whereas in an active matrix display, each pixel comprises a memory and each row of pixels is sequentially loaded with data.

With the widely divergent use of electronic devices comprising displays, for instance, laptop computers, mobile phones, etc..., various display technologies have been employed, e.g. liquid crystal display (LCD) and light-emitting diode (LED) display. An important distinction between these two technologies is that a LED is an emissive device that has power efficiency advantages over non-emissive devices such as LCDs. In an LCD, a fluorescent backlight is provided which is normally turned on during the entire period use of the display, thereby dissipating power even for pixels that are in the off-state. In contrast, a matrix LED display only illuminates those pixels that are activated and, consequently, no power is dissipated for pixels that are in the off-state. Consequently, a display employing a LED pixel structure can reduce power consumption, which is especially advantageous for the use in portable electronic devices which depend on a battery as a power source.

However, although a display employing a LED pixel structure can reduce power consumption, such a pixel structure may exhibit non-uniformity in intensity, which is attributable to many sources, two of which, i.e. threshold voltage drift of the drive transistor and transistor non-uniformity due to manufacturing, are acknowledged in WO 98/48403. By incorporating a current source into the LED pixel structures that reduces current non-uniformities and threshold voltage variations in the "drive transistor" of the pixel structure, said non-uniformities in intensity are also reduced.

However, other phenomena may give rise to non-uniformity in intensity. In particular, the LEDs comprised in a display receive different currents depending on the information to be displayed during its use. This results in a non-homogeneous burn-in of the display which becomes unacceptable at levels where the change, usually a decrease, of the light output exceeds approximately 2 to 3%.

In general, it is desirable to gain effective control over the light output of light-emitting diodes. Accordingly, it is an object of the present invention to provide a display device of the above-mentioned type in which the drawbacks of insufficient control and/or change of light output are obviated or at least substantially reduced.

To this end, the display device according to the invention is characterized in that the driving unit comprises means for measuring the voltage across the light-emitting diode and means for adjusting the drive signal for the light-emitting diode dependent on the measured voltage. It is preferred that the display device comprises means for determining the change of light output from the measured voltage and/or that the display device comprises a memory for storing the measured value or a value derived therefrom.

The light output (usually expressed in Cd/m^2) of LEDs is roughly proportional to the current and is defined as the product of the current and the efficiency as a function of time. During operation at constant current, a voltage increase was measured along with a decrease of light output. It was found that this voltage increase and light output decrease are correlated. After measuring the voltage, e.g. an analytical expression of the relationship between the increase of voltage and decrease of light output or a so-called Look-Up-Table (LUT) sampled in time can be used to determine the additional charge to be injected in a particular LED for it to maintain a (substantially) constant light output with reference to, for instance, an as yet unused LED. Subsequently, the total amount of charge injected during the pulse sequence is modified to compensate for the light output degradation.

Although the invention is certainly useful in devices equipped with a single light-emitting diode, such as calibrated light sources and warning lights which should consistently emit a specified amount of light, it is in particular useful in display devices comprising a plurality of light-emitting diodes, such as segments or pixels. In such LED displays, the invention reduces or obviates the effects of non-homogeneous burn-in of the display, by adjusting the drive signal (which is preferably a current) and thus the light output of one or more of the LEDs, preferably of all the LEDs, to a predetermined level, for instance, that of an as yet unused LED. The advantages of the present invention are especially noticeable in so-called organic and polymer LEDs, because non-homogeneous

burn-in has hitherto been an imminent difficulty for the practical use of called organic and polymer LEDs.

In display applications, the diodes are arranged in a matrix of rows and columns and the display device further comprises a column driver (sometimes also referred to as 'data generator') and a row driver (sometimes also referred to as 'select generator'). It is preferred that said memory is sufficiently large to store the measured values of an entire row or column or of the entire display.

The drive signal for the light-emitting diode is preferably adjusted through amplitude modulation (AM) and/or through pulse width modulation (PWM). The AM and PWM according to the present invention are preferably added to the AM and PWM that are usually already used to control, e.g., the shades of grey or brightness of the display elements.

It is preferred that the display device according to the invention comprises means for measuring a threshold voltage of the light emitting diode, and means for adjusting the drive signal for said light emitting diode, dependent on the measured threshold voltage. One of the characteristics of a LED is that the light emission starts when the voltage across the light-emitting diode is higher than a threshold voltage. It was found that an increase of this threshold voltage and a decrease of the light output due to burn-in, are correlated. After determining the threshold voltage, e.g. an analytical expression of the relationship between the increase of the threshold voltage and the decrease of light output or a LUT sampled in time can be used to determine the additional charge to be injected in a particular LED for it to maintain a (substantially) constant light output with reference to, for instance, an as yet unused LED. Subsequently, tot total amount of charge injected during the pulse sequence is modified to compensate for the light output degradation. The threshold voltage can be determined when the LED is switched on, for example, by monitoring the current through the LED. The current through the LED shows a steep increase when the voltage across the LED becomes larger than the threshold voltage. Alternatively the onset of light emission can be monitored.

It is to be noted that the resistive load of rows and columns causes a voltage drop which should be accounted for when measuring the exact values of the voltage across the emitting pixels. To avoid excessive compensation when some unexpected situations occur at a pixel, e.g. pixel shortage or growth of a so-called black spot, it is desirable to integrate over time the correction factors and monitor the average value so that the compensation can be disabled, if necessary.

To prolong the life span of the display device, one can gradually dim the brightness of the display during its lifetime. For instance, once the (average) AM/PWM correction reaches a certain limit, a dimming state of the display can be implemented the next time the display is used (or after a screensaver is turned off).

Moreover, temperature dependence of the light output of the display device according to the present invention can be reduced considerably by means of a temperature sensor and by implementing a temperature-dependent dimming or enhancing state.

Although current driving is generally considered to be more robust, it is also possible to carry out the correction if voltage driving is used. In that case, a current-measuring circuit should be incorporated.

It is to be noted that Japanese patent publication 07226536 discloses a LED colour information display board which is said to exhibit accurate 'colour expression'. This accurate colour expression is achieved by measuring the forward direction voltage across one of three LEDs comprised in one pixel. The measured value is inputted in a programmable constant current circuit and the value of the current applied to the red colour LED is controlled in dependence on this measured value. In other words, the technology according to this publication is based on the presumption that the rate of degradation in each LED comprised in one pixel is equal. In contrast, the present invention measures a voltage across a certain LED and subsequently provides an adjusted current through the same LED.

The invention will be further explained with reference to the drawings in which an embodiment of the display device of the invention is schematically shown.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the Figures.

Fig. 1 schematically shows a cross-section of part of an electroluminescent display device in accordance with the present invention.

Fig. 2 shows an equivalent circuit diagram of a display device according to the present invention.

Figs. 3 to 5 show examples of drive signals for driving the display device according to Figs. 1 and 2.

Fig. 1 shows part of an electroluminescent display device comprising driving means 1 and an active or emissive layer 2 comprising, for instance, a conjugated polymer-like PPV (poly(p-phenylene vinylene)) or a PPV-derivative, arranged between two patterned electrode layers of an electroconductive material, i.e. column or data electrodes 3 and row or selection electrodes 4. Thus, a matrix of light-emitting diodes (LEDs) is formed by means of

the intermediate active material. At least one of the electrode patterns is transparent to the emitted light in the active layer 2.

During operation, the column electrodes 3 are driven in such a way that they are at a sufficiently high positive voltage relative to the row electrodes 4 to inject holes in the active layer 2. The material of the column electrodes 3 is usually a transparent conductive oxide (TCO), such as indium oxide or indium tin oxide (ITO). ITO is particularly suitable in that it has a good work function, a high electric conductance and a high transparency in the visible spectrum.

The selection electrodes 4 serve (relative to the electrodes 3) as negative electrodes for the injection of electrons in the active layer 2. The material for the selection electrodes 4 may be, for instance, aluminium or a material having a low work function, such as indium or magnesium.

Fig. 2 schematically shows an equivalent circuit diagram of a part of a matrix of such LEDs having n rows and m columns. This diagram shows that the driving means 1 include a row selection circuit 5 (for example, a multiplex circuit) and a data register 6. Information presented from the exterior, for example a video signal, is processed in a control unit 7 which, dependent upon the information to be displayed, loads the individual parts of the data register 6. The row-selection voltages are presented by the row-selection circuit 5. Mutual synchronisation between the selection of the rows and the presentation of voltages to the column electrodes 4 takes place by means of the control unit 7 via control lines 8 and 9.

For details on the above-mentioned electrodes, suitable conjugated polymers for use in the active or emissive layer, thickness of these layers, and substrates for the LED structure, reference may be made to International Patent Application PCT/IB96/00414 (Publ. No. WO 96/36959). The advantages of the present invention are especially noticeable in organic and polymer light-emitting diodes.

Embodiment 1: Pixel at a time addressing

Fig. 2 comprises a voltage measurement capability 10 on each column, probing the voltage after each current source 11. In this first embodiment, the LEDs 12 in each row line 4_1 .. 4_n are addressed one at a time, with the driving scheme illustrated in Fig. 3.

In one possible example of row selection, at time t=0, a line is selected for addressing as the row voltage applied is reduced from non-selection voltage V_{nonsel} to

selection voltage V_{sel}. Current is then applied to each LED sequentially for a period of t_p (t_p is the line time divided by the number of columns, m). The voltage, $V_{measure}$, at each column is first probed during the short test current pulse with amplitude $I_{measure}$. This $V_{measure}$ value is transferred to the data register 6 and stored in memory 14. Here, the voltage of the diode is calculated as follows

$$V_{LED} = V_{measure} - V_{sel} - I_{measure} * (R_{row} + R_{col})$$

where R_{row} (R_{col}) are the resistances of the row (column) electrodes from the drivers to the actual pixel being addressed. The actual value of V_{LED} is a measure of the degradation of the LED and hence of its light emission efficiency. Depending upon V_{LED}, the driving current (I_{drive}) is modified to compensate for the degradation of the LED. The amount of current correction may be determined, e.g., with reference to a tabulated Look-Up-Table or LUT 13, or could be calculated by using an analytical expression.

The analytical expression and the LUT can be established, for instance, by measuring the voltage and the light output of a specific type of LED at a constant driving current. The measured values can be curve-fitted so as to obtain an analytical expression (e.g., an exponential or polynomial equation) or inputted in a LUT.

As mentioned above, compensation may take the form of a modification in pulse width (in a pulse width modulation scheme - dashed line in Fig. 3) or in current amplitude (in an amplitude modulation scheme - dotted line in Fig. 3). At the end of the line time, the row voltage reverts to V_{nonsel}, and the following row is addressed in the same manner.

An advantage of this embodiment is that memory 14 need only be a small one pixel memory. This method can advantageously be used for driving segmented displays, where the number of display segments (pixels) is small and hence t_p is large.

Embodiment 2: Line at a time addressing with line memory

In this embodiment, all the pixels of one line are addressed simultaneously. The driving scheme is shown schematically in Fig. 4. Once again, a row is selected by reducing the row voltage to V_{sel}. Now however, all the pixels in the row line are addressed simultaneously by all the current sources. As a consequence, the pixels are all addressed

close to a full line time, t_{line}, which makes this method also suitable for driving larger displays.

Determination of the individual pixel voltages proceeds similarly to embodiment 1, making use of the small measurement current pulse of amplitude $I_{measure}$ to measure $V_{measure}$ using the voltage probes. Once again, the voltage at the pixels must be determined by correcting for the resistive voltage losses along both the row and columns, as was the case in embodiment 1. In carrying out this correction, it should be appreciated that the current along the row now varies, moving further away from the driver, as all the LEDs are being probed simultaneously. All these pixel voltages are subsequently stored in memory 14, which in this case is a line memory, and used to determine the modification in the driving current (I_{drive}) needed to compensate for the associated pixel degradation. Again, either LUTs or analytical functions may be realised as a change in either pulse width or amplitude of the driving current.

At the end of the line time, the row voltage reverts to V_{nonsel}, and the following row may be addressed in the same manner.

In embodiments 1 and 2, the degradation compensation is being carried out dynamically (i.e. just before the pixels are driven). In many cases, the pixel degradation is rather gradual, and it may only be necessary to periodically probe the pixel voltages and then use the same compensation values for longer periods of time, perhaps up to several hours. This requires a frame memory 14.

Embodiment 3: Line at a time driving with a frame memory

In this embodiment, the memory 14 is a frame memory which is used to store the measurement voltages of all the pixels in the display. The driving scheme is shown in Fig. 5. In the first frame, all the pixels in the display are addressed with the measurement current ($I_{measure}$), and the pixel voltages, measured in a similar manner as in embodiment 2, are stored in the frame memory 14. In the second and subsequent frames, the driving currents are modified according to the content of the frame memory 14. Once again, either LUTs or analytical functions may be used to determine the modified currents, and the modification may be realised as a change in either pulse width or amplitude of the driving current.

The display continues to be driven with the same compensation for a predetermined period of time, at which point the frame memory 14 is again refilled with the

new pixel voltages and a new set of compensation values is determined. The time between subsequent filling of the frame memory 14 can be a fixed interval, or could be associated with the start of the display, or with the switching of the display to another mode of operation (such as when a screensaver becomes operational).

The invention is not limited to the above described embodiments which can be varied in a number of ways within the scope of the invention.

In summary, the invention relates to a display device comprising one or more display elements, at least one of which comprises a light-emitting diode, and a driving unit for driving the one or more display elements. The driving unit comprises means for measuring the voltage across the light-emitting diode and means for adjusting the drive signal for the light-emitting diode, dependent on the measured voltage.

Embodiment 4: pixel driving proportional to the pixel working voltage

In this embodiment of the display device according to the invention comprises means for measuring the voltage across the light emitting diode, and means for adjusting the drive signal for said light emitting diode, dependent on the measured voltage. More particular, the display device comprises means to adjust the drive signal through pulse width modulation. The driving unit comprises means for increasing the pulse width of the drive signal for the light emitting diode by an amount depending on the working voltage across said light emitting diode. The working voltage is the voltage across the light emitting diode which yields the programmed current through the emitting diode:

- The current pulses are switched on at time T_{on}.
- The switch-off time T_{off}' is, to a close approximation, a function of the change of the working voltage ΔV_{pix} across the light emitting diode due to burn-in:

$$T_{off}' = T_{off} + (\alpha \cdot \Delta V_{pix})$$

Where T_{off} is the switch-off time for a pixel which has no burn-in, and α is a proportionality constant. In the case of burn-in, the working voltage across the LED is $V_{pix}' = V_{pix} + \Delta V_{pix}$, where V_{pix} is the working voltage across a LED with no burn-in. Thus:

$$T_{off}' = T_{off} - (\alpha \cdot V_{pix}) + (\alpha \cdot V_{pix}')$$

It is noted that (α x U_{pix}) is independent of the burn-in, and that $(\alpha \cdot V_{pix})$ is constant when the LED is driven with constant current amplitude. In this case:

$$T_{off}' = \text{constant} + (\alpha \cdot V_{pix}')$$

Thus, the switch-off time T_{off}' shows a linear dependent on the working voltage across the LED.

The switch off time may be delayed for each pixel independently. The higher the voltage V_{pix}' across the LED during the pulse, the larger the delay until the current is switched off. The proportionality constant α may be chosen such that the delayed switch-off time compensates the effects of LED burn-in.

In the case that pulse width modulation of the current pulse is used for the gray scaling, it is preferred that the start of the current pulse T_{on} is modulated according to the gray scaling. This allows that the switch-off time T_{off}' is only a function of the pixel voltage V_{pix}' and therefore is not dependent on the gray scaling.

When amplitude modulation of the current is used for the gray scaling, also V_{pix} will change when the amplitude of the current changes. Thus, a change in the amplitude of the current may also influence the switch-off time T_{off}'. This effect may be, at least partially, compensated by choosing an appropriate proportionality constant α.

Fig. 6 shows an implementation of this embodiment of the invention. The hardware for one segment driver is shown in Fig. 6a, which hardware allows for the delayed switching off. The sequence of display driving is presented in Fig. 6b:

- At the beginning of each current pulse (at T_{on}), the voltage V_{off} is set to zero, and the bypass transistor 20 is disabled. All the programmed current is forced through the LED.
- At a certain time (in this example at the time T_{off}) the voltage V_{off} starts to increase linearly. As soon as this V_{off} is equal to the working voltage V_{pix}' of the concerned diode, the bypass transistor is activated and will short the programmed current. This will prevent the current from flowing through the LED, and the LED will stop with light emission.
- Finally, a new row is addressed, V_{off} is set back to zero, and the currents are reprogrammed for the next selected pixel in the multiplex sequence.

This embodiment allows a very cheap implementation in a driver IC, without extensive use of hardware. A simple comparator is needed per segment, to compare the V_{off} with the actual V_{pix}'. Moreover, no memory is needed to store the result of the measurement of V_{pix} or to store a LUT. As a consequence, no complicated 'decide logic' is needed, which converts the measured V_{pix}' to a different current amplitude or pulse width.

Another important advantage of this embodiment is that no measuring pulse is needed (as shown in Fig 3 and 4). This allows using the available time fully for displaying, instead of calibration also.

Embodiment 5: pixel driving proportional to the pixel threshold voltage

In this embodiment of the display device according to the invention comprises means for measuring the threshold voltage of the light emitting diode, and means for adjusting the drive signal for said light emitting diode, dependent on the threshold voltage. More particular, the display device comprises means to adjust the drive signal through pulse width modulation. The driving unit comprises means for increasing the pulse width of the drive signal for the light emitting diode by an amount depending on the threshold voltage of said light emitting diode:

- The current pulses are switched on at time T_{on}.
- The switch-off time T_{off}' is, to a close approximation, a function of the change of the threshold voltage $\Delta V_{threshold}$ across the light emitting diode due to burn-in:

$$T_{off}' = T_{off} + (\alpha \times \Delta V_{threshold})$$

Where T_{off} is the switch-off time for a pixel which has no burn-in, and α is a proportionality constant. In the case of burn-in, the threshold voltage of the LED is $V_{threshold}' = V_{threshold} + \Delta V_{threshold}$, where $V_{threshold}$ is the threshold voltage of a LED with no burn-in. Thus:

$$T_{off}' = T_{off} - (\alpha \times V_{threshold}) + (\alpha \times V_{threhold}')$$

It is noted that (α x $V_{threshold}$) is independent of the burn-in, and is independent of current amplitude with which the LED is driven. In this case:

$$T_{off}' = \text{constant} + (\alpha \times V_{threshold}')$$

Thus, the switch-off time T_{off}' shows a linear dependent on the threshold voltage of the LED

The switch off time may be delayed for each pixel independently. The higher the threshold voltage $V_{threshold}$' of the LED during the pulse, the larger the delay until the current is switched off. The proportionality constant α may be chosen such that the delayed switch-off time compensates the effects of LED burn-in.

In the case that pulse width modulation of the current pulse is used for the gray scaling, it is preferred that the start of the current pulse T_{on} is modulated according to the gray

scaling. This allows that the switch-off time T_{off}' is only a function of the pixel threshold voltage $V_{threshold}$' and therefore is not dependent on the gray scaling.

It is believed that the burn-in of a LED results, among others, in an increase of the threshold voltage of said LED. The electrical schematic of a LED display pixel can be given as a diode, with a parallel capacitance between the two electrodes. Due to the combination of the capacitance between the two electrodes and the current driving, the onset of light emission is delayed: At the beginning of a current pulse, as long as the voltage across the LED is lower than the threshold voltage of said LED, the constant current is used to charge up the capacitance C_{pix}, instead of generating light (see Fig. 7). At the end of the current pulse (when the current is forced to zero), the charge in the capacitance is removed.

As long as the voltage across the light-emitting diode 12 is lower than the threshold voltage of said diode 12, the capacitance C_{pix} is charged up. The higher the diode threshold voltage, the more current is used for charging the capacitance C_{pix}, instead for light emission. This threshold voltage is not identical for the different pixels in the display device: Pixels that are switched on often, show a higher threshold voltage than pixels that are seldom used. Therefore, two display pixels with a different threshold voltage (other than that, they are identical) will not show the same brightness if being addressed in the display device. Pixels that are used more often will be less bright than pixels that are only rarely used. For example:

- Assume a display with 80 frames per second. That means that each display pixel may be addressed up to 80 times per second, and therefore emits a light pulse up to 80 times per second.
- Assume a 1:100 multiplexed display. That means that this display device allows addressing 100 different pixels with the same electrode. This results in a maximum of 8000 pulses per second (80 x 100).
- Assume a LED pixel has a capacitance C_{pix} of approximately 0.25 nF, and a current of 20 mA for full illumination of a pixel. With the current pulse of one electrode, all pixel capacitance connected to this electrode needs to be charged and discharged. In this case, 100 x 0.25 nF = 25 nF have to be charged and discharged with a frequency f of 8000 times per second.
- Assume that the display contains some often-used pixels and some pixels that are not often used. In such case, the difference in the threshold voltage ΔV may be about 3V.

The current I that is used for charging and discharging is therefore:

$I = \Delta V \times C \times f$

$I = 3\ V \times 25\ nF \times 8000\ Hz$

$I = 0.6\ mA$

Thus, in this example approximately 20 mA – 0.6 mA = 19.4 mA are available for illumination. With other words, the often-used pixel will have a reduction in emission of about 3 %. This may show as some kind of burn-in effect. This burn-in effect can be compensated by a driving unit which comprises means for increasing the pulse width of the drive signal for the light emitting diode by an amount depending on the threshold voltage of said light emitting diode.

While this invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.

CLAIMS:

1. A display device comprising one or more display elements, at least one of which comprises a light-emitting diode, and a driving unit for driving the one or more display elements, **characterized in that** the driving unit comprises means for measuring the voltage across and/or the current through the light-emitting diode and means for adjusting the drive signal for the light-emitting diode, dependent on the measured voltage and/or current.

2. A display device as claimed in claim 1, wherein the display device comprises means for determining the change of light output from the measured voltage.

3. A display device as claimed in claim 1, wherein the display device comprises a memory for storing the measured value or a value derived therefrom.

4. A display device as claimed in claim 1, wherein the display further comprises at least one current source and a voltage measurement capability for probing the voltage between the current source and at least one of the diodes.

5. A display device as claimed in claim 3, comprising a number of diodes, which are arranged in rows and columns, wherein the memory is sufficiently large to store the measured values, or the values derived therefrom, of an entire row or column.

6. A display device as claimed in claim 3, wherein the memory is sufficiently large to store the measured values, or the values derived therefrom, of each the diode comprised in the display.

7. A display device as claimed in claim 2, wherein the means for determining the change of light output from the measured voltage employs a Look-Up-Table or an analytical expression containing the change of light output as a function of the change of the voltage across the light-emitting diode.

8. A display device as claimed in claim 1, wherein an enhancing or dimming state of the display is implemented to compensate temperature variations in and/or prolong the life span of the display device.

9. A display device as claimed in claim 1, which comprises an active layer of an electroluminescent material situated between a first and a second electrode, at least one of the electrodes being transparent to light to be emitted by the active layer, and one of the electrodes comprising a material which can be suitably used to inject charge carriers.

10. A display device as claimed in claim 1 or 2, wherein the display device comprises means for measuring a threshold voltage of the light emitting diode, and means for adjusting the drive signal for said light emitting diode, dependent on the measured threshold voltage.

11. A display device as claimed in claim 10, wherein the display device comprises means to adjust the drive signal through pulse width modulation, and wherein the driving unit comprises means for increasing the pulse width of the drive signal for the light emitting diode by an amount proportional to the threshold voltage of said light emitting diode.

12. Electronic device comprising a display device as claimed in claim 1.

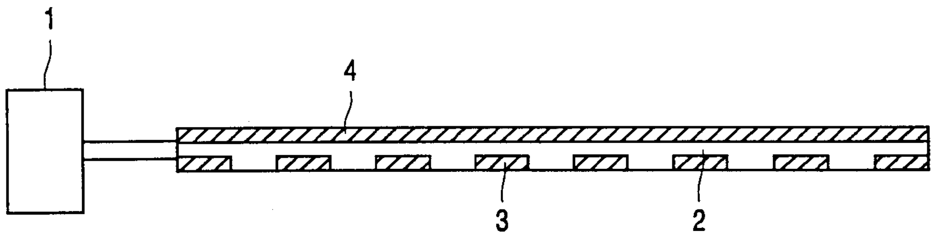

1
4
3
2

FIG. 1

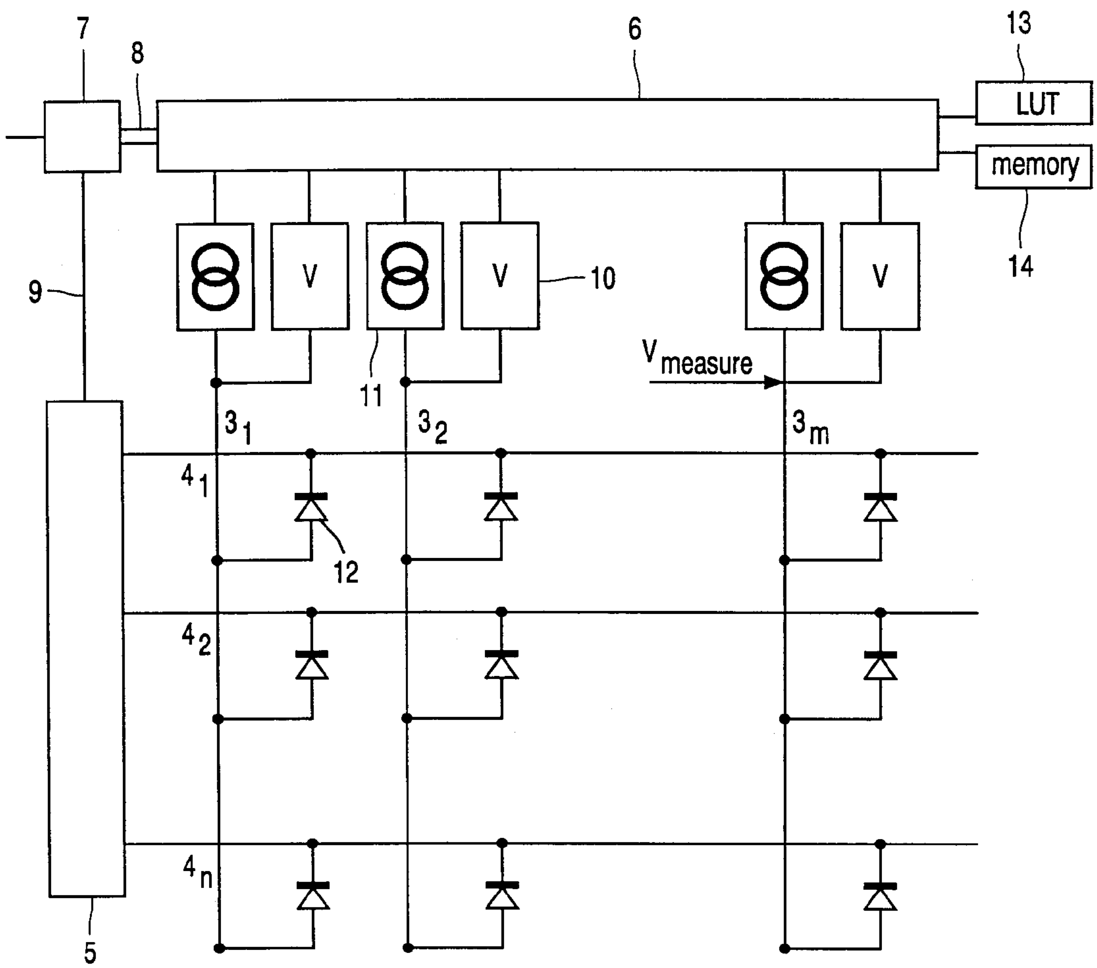

7
8
6
13
LUT
memory
14
9
V
V
10
V
11
$V_{measure}$
3_1
3_2
3_m
4_1
12
4_2
4_n
5

FIG. 2

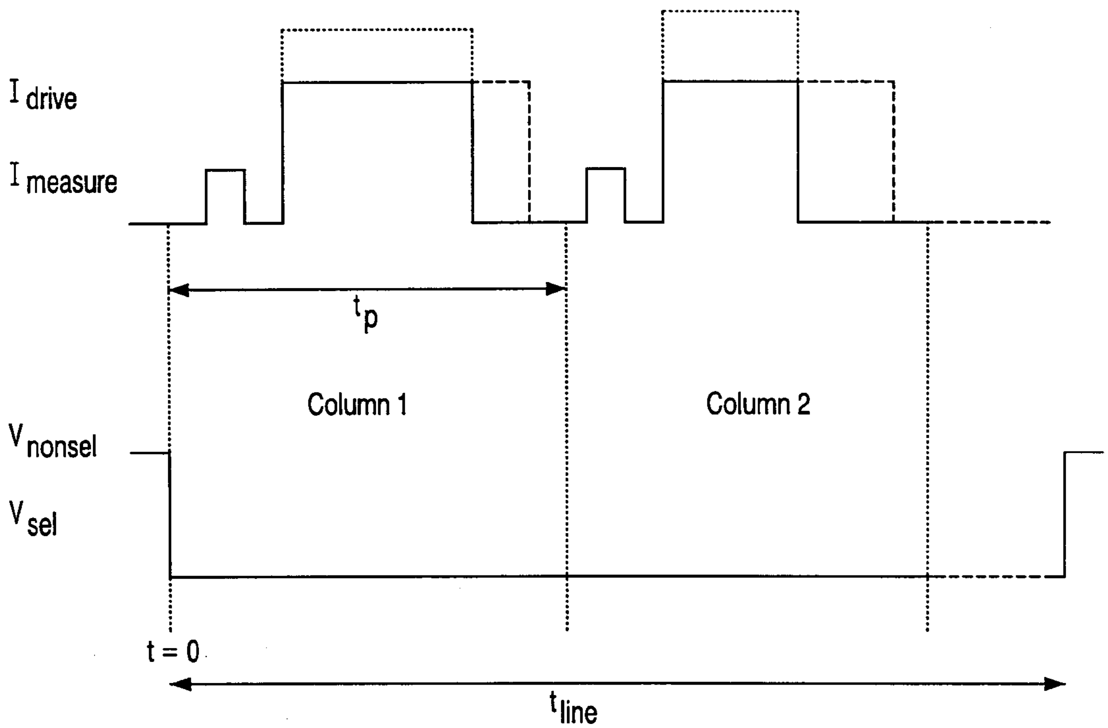

I drive
I measure
t_p
Column 1
Column 2
V_{nonsel}
V_{sel}
t = 0
t_{line}

FIG. 3

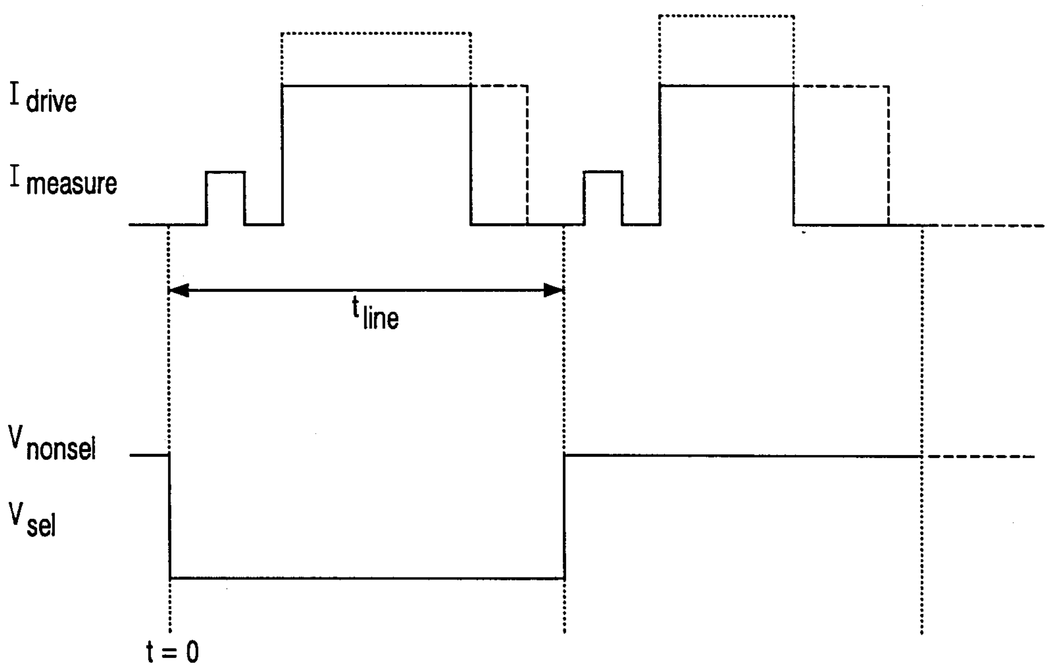

I drive
I measure
t_{line}
V_{nonsel}
V_{sel}
t = 0

FIG. 4

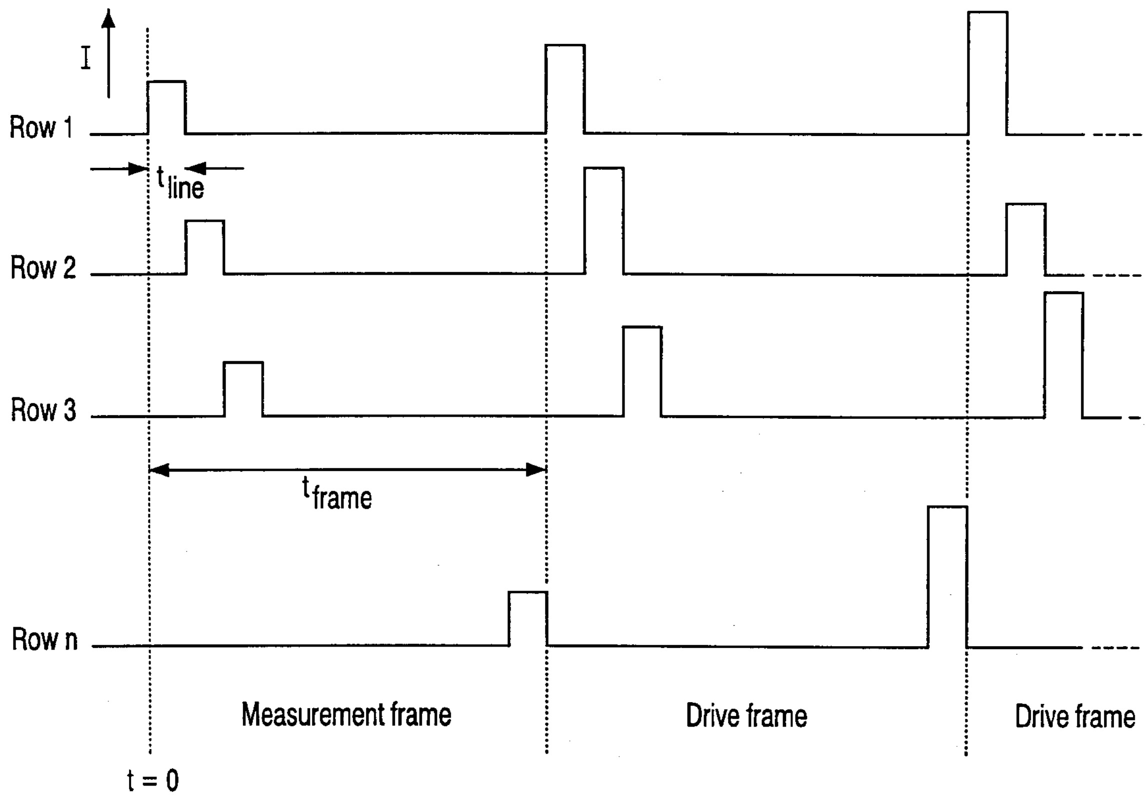

I
Row 1
t_{line}
Row 2
Row 3
t_{frame}
Row n
Measurement frame
Drive frame
Drive frame
t = 0

FIG. 5

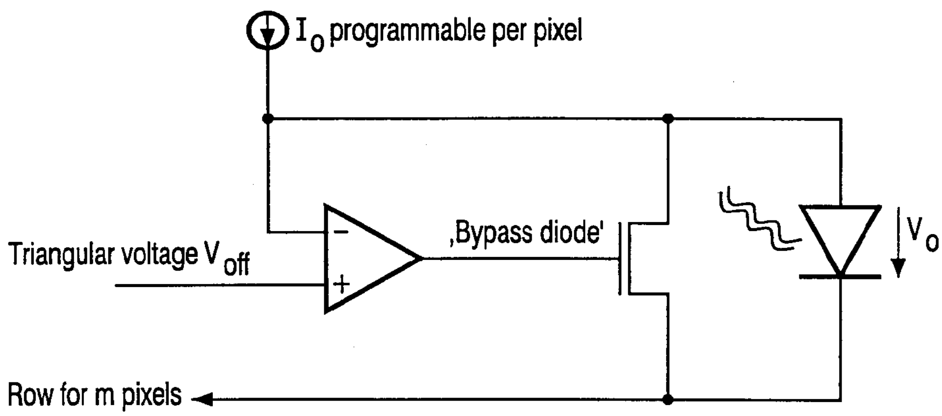


FIG. 6a

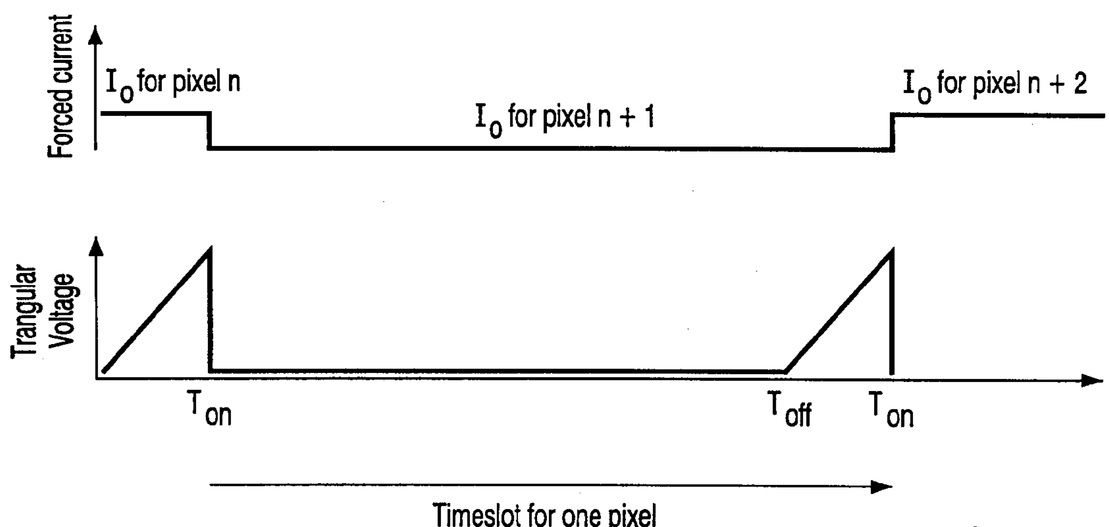


FIG. 6b

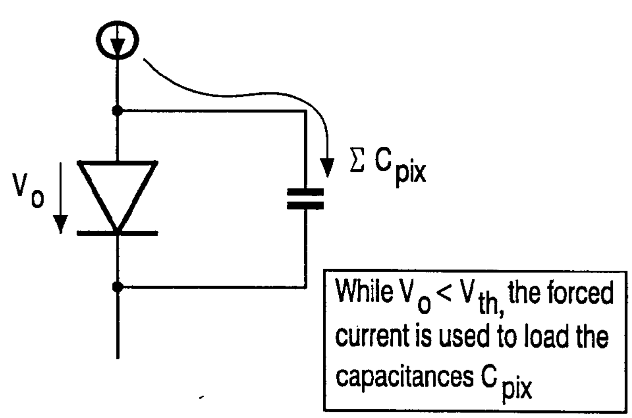


FIG. 7

INTERNATIONAL SEARCH REPORT

Interr nal Application No
PCT/EP 00/09765

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09G3/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 52182 A (UNISPLAY SA ;SALAM HASSAN PADDY ABDEL (GB)) 19 November 1998 (1998-11-19)	1-9,12
A	page 8, paragraph 4 -page 9, paragraph 2 page 12, paragraph 5 -page 15, paragraph 1 page 17, paragraph 2 ---	11
X	EP 0 905 673 A (MITSUBISHI CHEM CORP ;SARNOFF CORP (US)) 31 March 1999 (1999-03-31) paragraph ‘0008! paragraph ‘0013! - paragraph ‘0025! paragraph ‘0071! - paragraph ‘0100! ---	1-3,5-7, 9,10,12
X	US 5 594 463 A (SAKAMOTO MITSUNAO) 14 January 1997 (1997-01-14) column 6, line 7 -column 10, line 61 -----	1-4,7-9, 12

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2001	18/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Amian, D

INTERNATIONAL SEARCH REPORT

ırmation on patent family members

Intern nal Application No
PCT/EP 00/09765

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9852182	A	19-11-1998	NONE		
EP 0905673	A	31-03-1999	JP	11219146 A	10-08-1999
US 5594463	A	14-01-1997	JP	7036409 A	07-02-1995
			JP	7036410 A	07-02-1995